Report No. FAA-RD-78-28

FOR FURTHER TRAN

ADA054141

AD No.
DDC FILE COPY

TESTS OF CRASH-RESISTANT FUEL SYSTEM FOR GENERAL AVIATION AIRCRAFT

William M. Perrella, Jr.

DEPARTMENT OF TRANSPORTATION · UNITED STATES OF AMERICA

MARCH 1978

INTERIM REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA/RD-78-28		12 32p.

4. Title and Subtitle	5. Report Date
TESTS OF CRASH-RESISTANT FUEL SYSTEM FOR GENERAL AVIATION Aircraft.	Mar[redacted]78
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
William M. Perrella, Jr	FAA-NA-77-48
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Federal Aviation Administration National Aviation Facilities Experimental Center Atlantic City, New Jersey 08405	11. Contract or Grant No. 184-521-100
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D.C. 20590	Interim rept. Feb[redacted]76-Jun[redacted]77
	14. [redacted]

15. Supplementary Notes

16. Abstract

A significant percentage of general aviation aircraft accidents result in post-crash fires due to the ignition of fuel spillage, often contributing injury or death to the aircraft occupants.

Testing was performed to demonstrate the performance of light-weight, flexible, crash-resistant fuel cells combined with the use of frangible fuel line couplings. Included in these tests were three full-scale crash tests of a typical light twin aircraft. In all of these tests, the crash-resistant fuel system performed satisfactorily.

17. Key Words	18. Distribution Statement
Crash-Resistant Fuel Cells Aircraft Fuel Tanks Crashworthy Fuel Cells	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	46	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

240 550

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

INTRODUCTION

Studies of aircraft accident records show that a significant percentage of fatalities result from postcrash fires. It is apparent that once ignition occurs in the presence of large quantities of spilled fuel, the survival chances of the aircraft occupants are greatly reduced; even when fire-fighting equipment is immediately on the scene. The only feasible way to decrease the incidence of postcrash fires is by the reduction of fuel spillage and ignition sources. Therefore, the Federal Aviation Administration (FAA) has initiated the present program to evaluate one way of preventing massive spillage of fuel during a crash; i.e., crash-resistant flexible bladder cells used with self-sealing frangible couplings at critical points in the fuel lines.

The U.S. Army has unquestionably established that fuel can be contained by flexible fuel tanks, thereby eliminating the potential of postcrash fire. These tanks, while very effective, impose weight and cost penalties which could be significantly reduced for general aviation aircraft. Consequently, the major thrust of this program was to develop effective low-cost, lightweight, crash-resistant fuel cells.

A contract was awarded to the Uniroyal Corporation to design and fabricate six crashworthy tanks, three right-hand and three left-hand, for the Piper Navajo aircraft. These tanks were to be equipped with Aeroquip® type DE5175-1-8A frangible couplings on the filler and vent fittings. The original contract specification is shown in appendix A.

DISCUSSION

TANK CONSTRUCTION.

Construction materials devised by industry to meet MIL-T-27422B provided a starting point for the program. The initial contract called for the construction of three left-hand tanks of two-ply construction, and three right-hand tanks of three-ply construction. To assist in reducing construction weight, the drop test requirement of the above specification was reduced to 39 feet. All tank fittings were initially specified to meet MIL-T-27422B requirements.

On August 13, 1975, a left-hand two-ply tank was filled with 59.2 gallons of water and dropped from a height of 39 feet. The tank successfully withstood the impact on its leading edge with no visible damage. Based on that fact, and the results of a full-scale aircraft crash test described later, it was decided not to fabricate two of the three-ply cells. In place of these cells, two single-ply types were specified. The tanks were to be fitted with Uniroyal designed fittings similar to MS33581, with the addition of a third ring. These fittings are lighter in weight and lower in cost than the Uniroyal Wall Expansion® and Fibre-Lok® fittings used on the other tanks, and have been demonstrated as satisfactory in 50-foot free-fall impacts when mounted in a

2 foot by 2 1/2 foot by 2 1/2 foot test tank per paragraph 4.6.6.2 of MIL-T-27422B. Table 1 summarizes the characteristics of the tanks delivered for testing at NAFEC.

TABLE 1. FUEL TANK CHARACTERISTICS

Tank Type	Qty.	Uniroyal Construction Code No.	Fabric Plies	Fabric Weight (oz/sq yd)	Total Weight of Fittings (lb)	Tank Weight (lb)
L. H.	3	* US758	2	12.75	6.50	27.0
R. H.	1	US759	3	12.75	7.76	38.0
R. H.	1	**US756	1	25.50	2.75	24.2
R. H.	1	US764	1	12.75	2.75	18.0

* One of these tanks successfully passed the 39-foot drop test.

**This material has FAA Technical Standard Order (TSO-C80) approval.

The main bladder cells with which the aircraft is normally equipped weigh 9.6 pounds each. Refer to figure 1. The contractor was required to perform the following material tests per MIL-T-27422B:

(1) Constant rate tear (4.6.5.1)
(2) Impact penetration (4.6.5.2)
(3) Impact tear (4.6.5.3)
(4) Panel strength calibration (4.6.5.4).

Table 2 shows the results of these tests. Of course, a lighter weight tank reinforcement is not as resistant to crash loads as heavier reinforcements.

As of this writing, there have been hundreds of crashes of military helicopters, and not a single fire-caused death has resulted. Such a record shows that the construction of these military tanks is at least adequate. The tanks may very likely be somewhat overdesigned. Tank crash loads in a small fixed-wing aircraft are generally less than in a rotor wing aircraft. A helicopter often has a significant vertical velocity component during a crash. There are generally concentrated mass loads high in the structure, such as engines and transmissions, which can break loose and impact a tank from above while lower structure impacts from below, due to deformation caused by ground contact. Additionally, helicopter tanks are often of a shape close to cubical, so that very little deformation is required to develop high hydraulic loads. In most fixed-wing aircraft, there are no heavy masses to sandwich a tank against the ground.

TABLE 2. PHYSICAL PROPERTIES OF FUEL TANK CONSTRUCTION (MIL-T-27422B)

Test Data Required	CONSTRUCTIONS US758 2-Ply 12.75 Oz. Fabric	US759 3-Ply 12.75 Oz. Fabric	US756 1-Ply 25.5 Oz. Fabric	US764 1-Ply 12.75 Oz. Fabric
Constant Rate Tear-Foot Pounds				
Parallel Warp	257	321	210	138
90° Warp	251	369	213.6	136
45° L Warp	299	417	224.9	121
45° R Warp	271	454	249.5	127
Impact Penetration - Drop Height Passed - Feet				
Parallel Warp	5.5	11	8.5	4.5
90° Warp	6	11	8.5	4.58
45° L Warp	6	11	8.5	4.67
45° R Warp	6	11	8.5	4.67
Impact Tear - Drop Height Passed - Feet				
Parallel Warp	6	10	7	1.67
90° Warp	5	9	9	2.00
45° L Warp	9	10	10	3.17
45° R Warp	9	10	10	3.17
Panel Strength Calibration-Pounds	17402	18134	17926	11718

Also, the shape of a typical wing tank is favorable in regard to hydraulic loads. Impacted against the leading edge, the tank volume will increase to a large percent of its former volume, so the hydraulic pressure will remain low. The primary design criteria for such tanks are tearing and puncture resistance. There are some aircraft which use belly tanks or nacelle tanks of compound shapes or shapes not conducive to volume increase upon impact. These tanks should be constructed per MIL-T-27422 to obtain the required degree of safety.

INSTALLATION OF TANKS IN AIRCRAFT.

As crash-resistant tanks are somewhat stiffer than standard bladder cells, they could not be installed in the opening in the wing normally used for that purpose. Figure 2 shows a two-ply tank, which is much stiffer than one of single-ply construction.

The crashworthy tanks were installed by removing the bulkhead rib at the wing root after the wing was removed from the aircraft. The tank was slid into the wing, after which the rib was riveted back in place, and the wing was reinstalled. Referring to figure 3, it is seen that the tanks occupy the wing leading edge, the most hazardous location. No modifications were done on the wing where the filler flange fitting, access, and gauge fittings were located. The frangible couplings (figure 4) were installed at the fuel outlet and vent fittings. As bulkhead ribs interfered with these fittings, 2-inch-diameter clearance holes were cut in the ribs. To provide a more severe operating condition for the couplings, aluminum tubing was used in lieu of the flexible tubing normally used for fuel lines. Actuating arms were installed to impact these lines when the arms contacted the ground during the crash (figure 5).

It was found that there was a decrease in the volumetric capacity of the crash-resistant tanks relative to the existing aircraft cells, each of which holds 59 gallons: the three-ply tank held 53 gallons, the two-ply, 55 gallons, and the single-ply US764 held 57.6 gallons. The reason for the decrease in capacity was that these preproduction tanks did not properly conform to the inner contours of the wing. In a production tank, the fit would have been much more precise, probably resulting in a reduction in volume of less than a gallon.

A crashworthy fuel tank must not fail when the aircraft experiences "survivable" crash accelerations. An aircraft crash is considered survivable if the acceleration levels and durations are within certain limits which do not result in fatal injuries to the occupants. These limits were defined by experimental tests with animals and humans. Reference 1 presents data from these tests, which are summarized here in figures 6 through 11. While the use of "survivability" is necessary to design a crashworthy fuel system, it must also be understood that fuel systems do not necessarily fail because of hydrodynamic loads induced by acceleration. Failure is also likely when a tank receives a large impact force distributed over a small area. While the local effects of such a load would be significant, the acceleration imparted to the aircraft would be small.

FULL-SCALE CRASH TESTS.

The crash tests were performed at the National Aviation Facilities Experimental Center (NAFEC) catapult facility. A compressed-air catapult was used to accelerate the test aircraft along a 90-foot track. At the end of the catapult stroke, the aircraft, which was pulled by its nose gear, was released to impact an earthen hill of 4° slope. At the base of the hill, a 12-inch by 12-inch I-beam was installed to break off the aircraft's landing gear. The nose gear was strengthened to withstand the catapult pulling force (figure 12), while the main landing gear mounting bolts were sawed in half to effect an easier separation from the wings. Spoilers were installed along the upper wing surface. At a distance of 10 feet from the I-beam, poles were sunk into the hill to a depth of 18 inches. These poles were spaced symmetrically off the centerline of the hill, at 42 inches and 108 inches each. The poles were hollow mild steel tubing, 4.375-inches outside diameter, 0.188-inch wall thickness, and were 10 feet in length. Small rock piles were located on the hill to further increase the severity of the crash condition (figures 13 and 14). There are no standards in general use for a crash site as is used in this type of test; hence, the selection of the type of poles, rocks, and hill was arbitrary. The crash site was intended to be at least as severe as a typical crash at an airfield involving airport structures such as approach lights. It is nevertheless recognized that the term "typical crash" is a misnomer. The crash accelerations were compared to case histories of actual crash accelerations obtained from reference 1 and presented in figures 9 and 10.

In all tests, the aircraft main tanks were filled with water. Accelerometers, CEC type 4-203-0001, were installed on the floor of the aircraft at the longitudinal center of gravity location (station 126). Accelerations in the vertical and longitudinal direction were recorded on an oscillograph. The data were filtered at 90 hertz (Hz).

RESULTS

The acceleration pulses had the general form illustrated in figure 15. Time zero started as the nose gear struck the I-beam, resulting in the initial spike shown. This spike, typical in all tests, was about 100 g's longitudinal, for a duration of 5 milliseconds. Following this event, for a period of 0.17 to 0.33 seconds or so, depending on the test, there was no one acceleration peak distinguishable from the accelerations caused by the vibration of the structure. The aircraft was decelerating at an average level of approximately 2 g's. During this period of time, the main landing gear was broken off. The main acceleration pulse was typically about 0.1-second duration, during which the aircraft was experiencing retarding forces from ground contact, as well as rock impacts. Only in test 3 did the pole impacts on the wing happen to coincide with the main acceleration pulse. After an analysis of the high-speed films, it was found that the pole impacts, which occurred approximately 0.21 seconds into the crash event, did not produce any significant acceleration peaks within the cabin of the aircraft. While the effect of these impacts on the wing was severe, resulting in much damage, the inherent chordwise

flexibility of the wing prevented the force transferral to the fuselage. This particular wing, as do most light aircraft wings, has a single spar to transmit wing-bending loads. Torsional stiffness is provided by two additional "spars", one near the leading edge, and one at the trailing edge. These are connected at the fuselage with one bolt each per side. Upon wing impact with the poles, these bolted connections failed, resulting in very low chordwise stiffness. This characteristic is considered very beneficial in regard to crashworthiness, since not only does it eliminate high peak accelerations from wing impacts, but also reduces the chance of fatal postcrash fires, since the wing itself is more readily torn from the aircraft than a stiffer type of wing.

It was necessary to keep the aircraft light in weight in order to obtain the most speed possible with the type of catapult used. In this regard, the empennage and engines were not installed on the airframe. From an analysis of the film, it was concluded that the probable effect of the engine mass on the local fuel cell impact loads would have been negligible. The dynamic behavior of the wing and aircraft after the impacts would have been significantly different, however, had the engines and empennage been installed.

Major results of the three crash tests are summarized in table 3. The first test evaluated three-ply and two-ply tanks. The left wing received the most severe impacts. It contained the two-ply tank, which, upon later visual inspection, was found to be undamaged. The self-sealing Aeroquip couplings all actuated with no leakage. The left wing was nearly torn from the fuselage, with only a small part of the spar web holding it (figures 16 and 17). Acceleration levels, shown in figure 18, show that this crash was survivable, with injury of the occupants likely if the standard aircraft seating and belts were used. The impact speed of the aircraft was 93 feet per second (ft/s).

TABLE 3. CRASH TEST DATA

Test No.	Date	Fuel Tank L. H.	Fuel Tank R. H.	Aircraft Weight lb: Empty	Aircraft Weight lb: Tanks Full	Impact Speed, Ft/s	Maximum Acceleration, g: Fwd	Maximum Acceleration, g: Up	Damage
1	2/18/76	2-Ply* US758	3-Ply US75[illegible]	1,700	2,600	93	15	5	None to either tank
2	8/8/76	2-Ply US758	Original Aircraft Bladder Cell	1,710	2,660	93	29	7.5	None to L. H. tank R. H. tank ruptured
3	5/18/77	2-Ply US758	Single-Ply US764	1,660	2,598	95	27	55	None to either tank

*This tank was previously drop tested from 39 ft.

Test 2 compared the existing aircraft bladder cell (right wing) with a two-ply crashworthy cell. The two-ply tank survived the 93-ft/sec impact with no damage, but the original bladder cell failed catastrophically, spraying out its contents almost instantaneously. The cell failed predominantly by tearing (figures 19 through 25). During impact, the aircraft rotated counterclockwise about its center of gravity as viewed from above, as the forces delivered to the left wing were higher due to the stiffening effect of the two-ply tank. It came to rest at about a 30° angle. Longitudinal accelerations peaked at about 29 g's. Only if proper seats, preferably with full restraints, had been used would this crash have been survivable. Under 5 percent of the aircraft involved in crashes will experience greater longitudinal accelerations than this case (figures 9 and 26).

Slight leakage was observed from both frangible couplings on the two-ply tank after this test. Inspection revealed this was caused by corrosion in the flapper valve assemblies. The tanks had been filled with water for several weeks prior to the test. As the couplings are designed to operate with aviation fuels, this leakage was not considered a problem which would occur in service.

Test 3 was performed to evaluate the performance of the lightweight single-ply tank, installed in the right wing. A two-ply tank was run concurrently. Both of these tanks survived the 95-ft/s impact with no damage discernable to a visual inspection (figures 27 through 29).

As in the previous test, survivability of the aircraft occupants would have required suitable seats and restraints. About 2 percent of aircraft involved in crashes will experience greater longitudinal accelerations, and about 3 percent will experience greater vertical accelerations (figures 9, 10, and 30). As the lightweight tank did not fail in this test, it was decided not to test the heavy single-ply tank. It is probable that crashworthy fabrics even lighter in weight than 12.75 ounce (oz) will be adequate. A tank fabricated from 8-oz fabic would weigh less than 15 pounds.

The results obtained show that effective crash-resistant fuel systems can be constructed which have small weight and volume penalties. The use of these systems would undoubtedly result in the saving of lives which otherwise would be lost in postcrash fires. Test procedures similar to those in MIL-T-27422, but reduced in severity, should be derived for the production of crash-resistant fuel cells for general aviation aircraft.

CONCLUSION

It has been demonstrated that light-weight, flexible, crash-resistant fuel cells used with self-sealing frangible fuel-line couplings can effectively reduce postcrash fuel fires in general aviation aircraft equipped with wing tanks.

REFERENCES

1. Crash Survival Design Guide, USAAMRDL Technical Report 71-22.

2. Dynamic Response of Structures, Pergamon Press, N. Y., 1971.

3. Piper Navajo Fuel Tanks, FAA Crash Resistant Modifications, Tanks and Testing, Uniroyal Report FC-1641-77, March 1977.

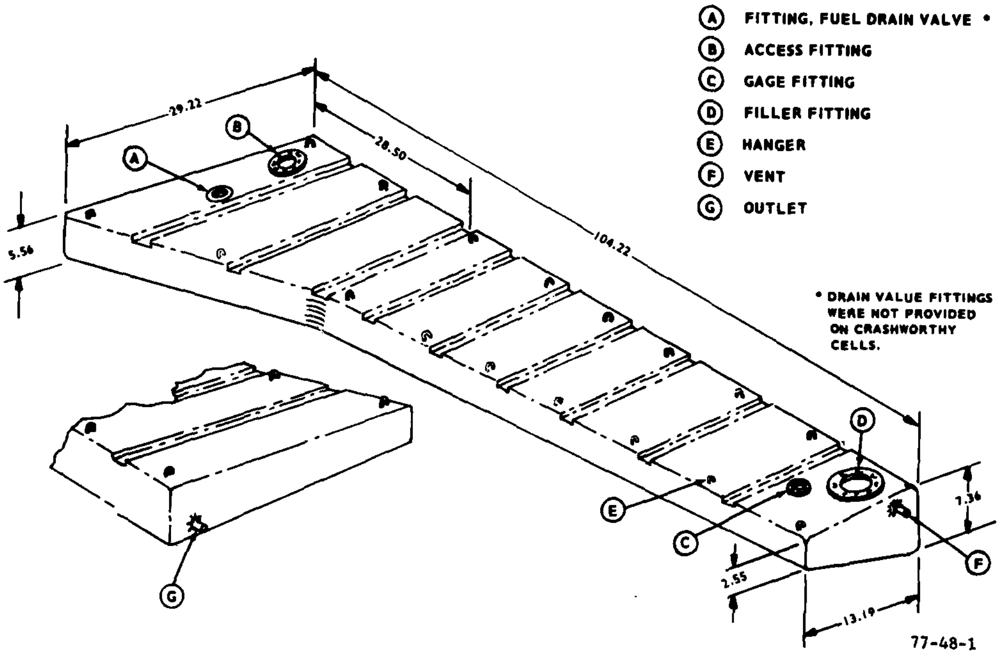

FIGURE 1. LEFT MAIN FUEL CELL, PIPER NAVAJO

FIGURE 2. TWO-PLY FUEL TANK

FIGURE 3. INSTALLATION OF TWO-PLY FUEL TANK

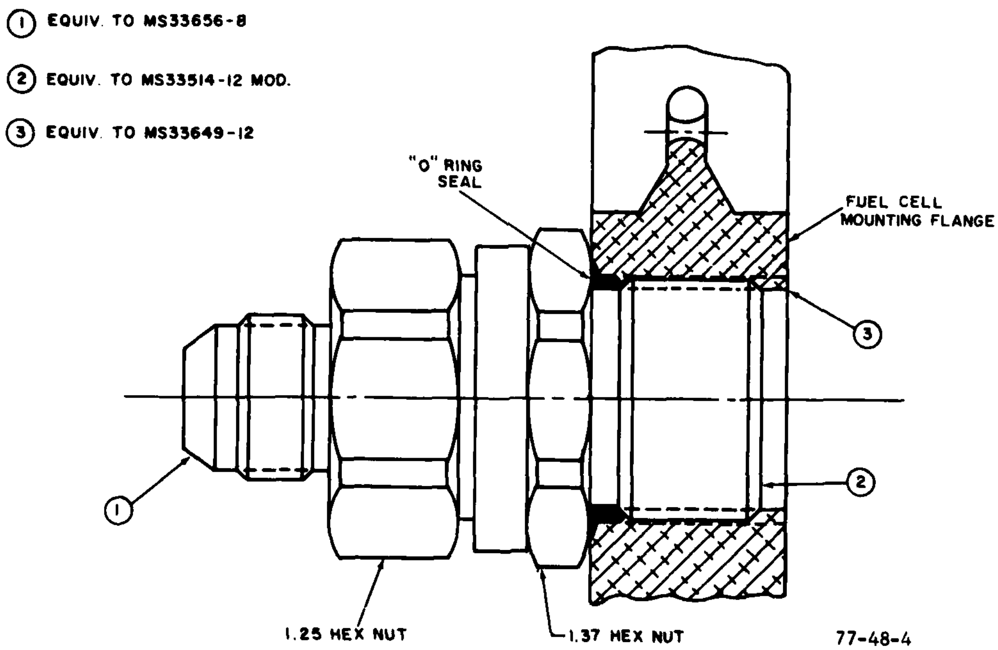

FIGURE 4. FRANGIBLE COUPLING MOUNTED TO FUEL CELL MOUNTING FLANGE

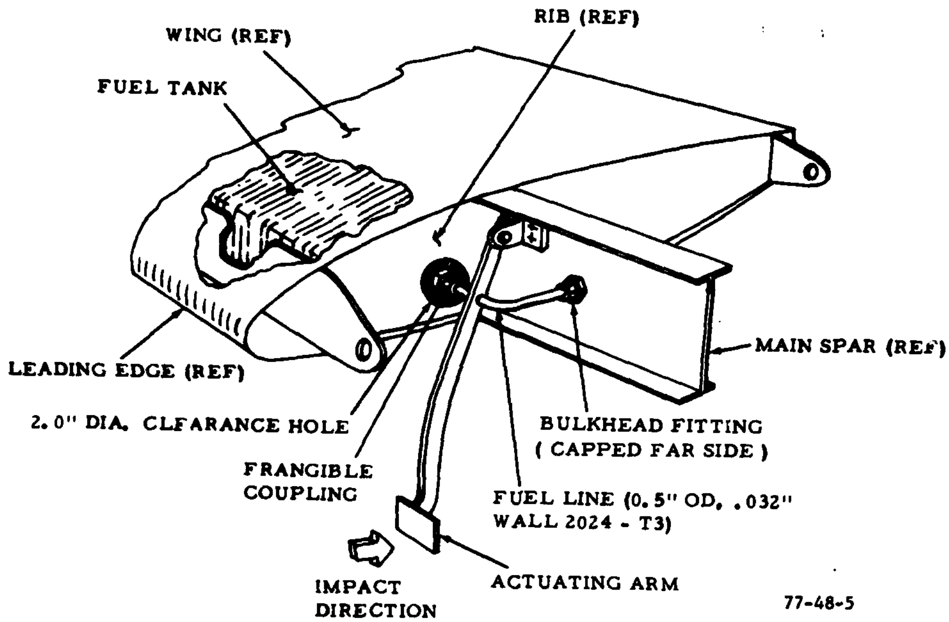

FIGURE 5. TYPICAL FRANGIBLE COUPLING INSTALLATION (WING ROOT)

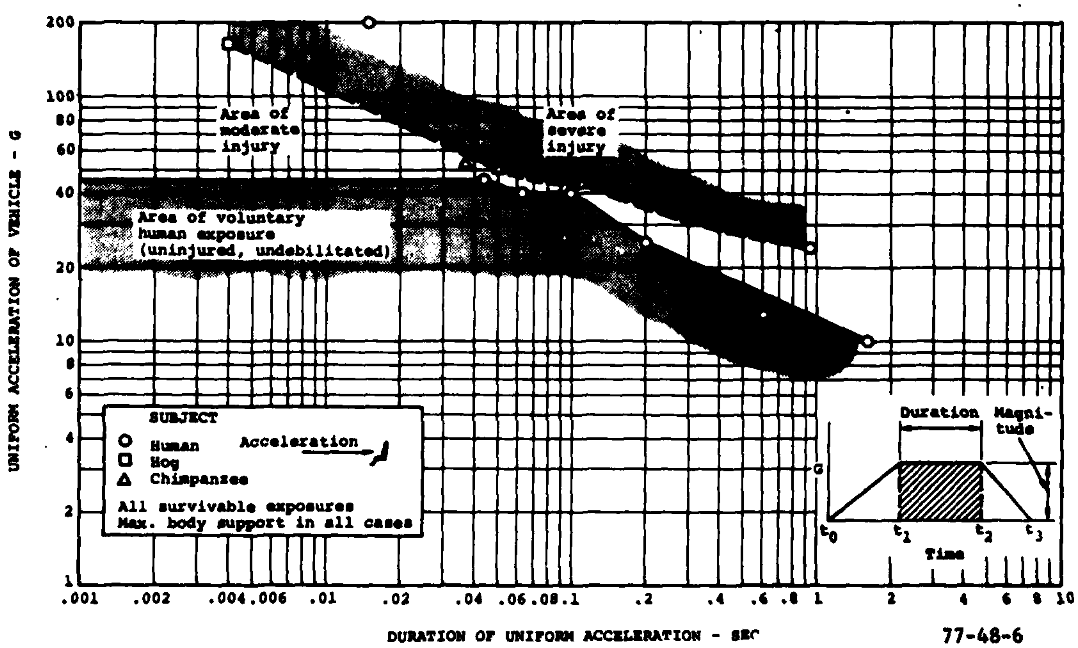

FIGURE 6. DURATION AND MAGNITUDE OF SPINEWARD ACCELERATION ENDURED BY VARIOUS SUBJECTS (TAKEN FROM REFERENCE 1)

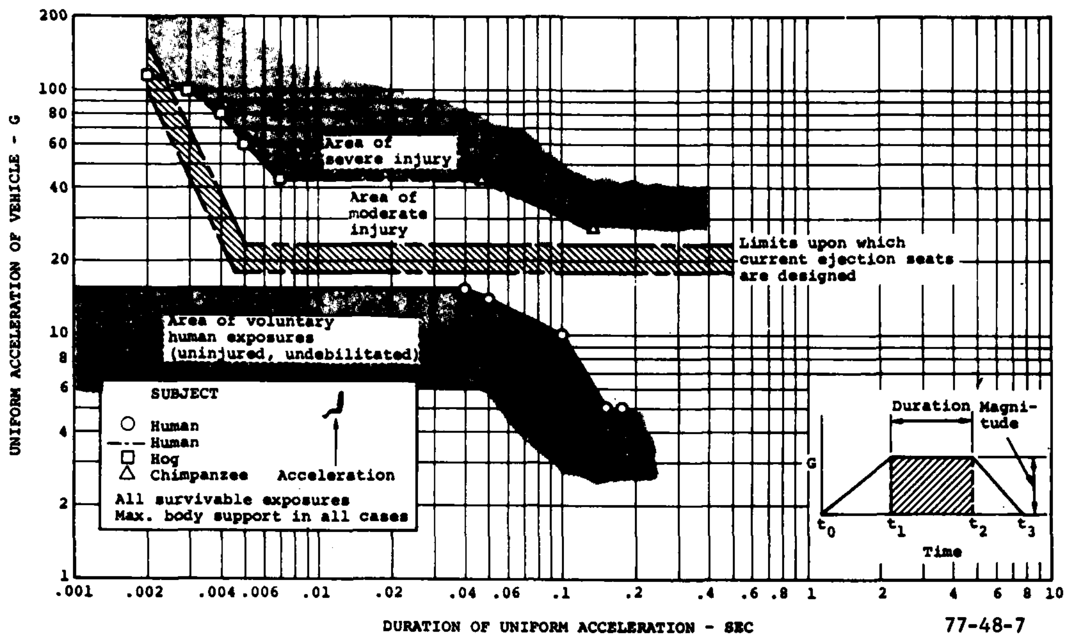

FIGURE 7. DURATION AND MAGNITUDE OF HEADWARD ACCELERATION ENDURED BY VARIOUS SUBJECTS (TAKEN FROM REFERENCE 1)

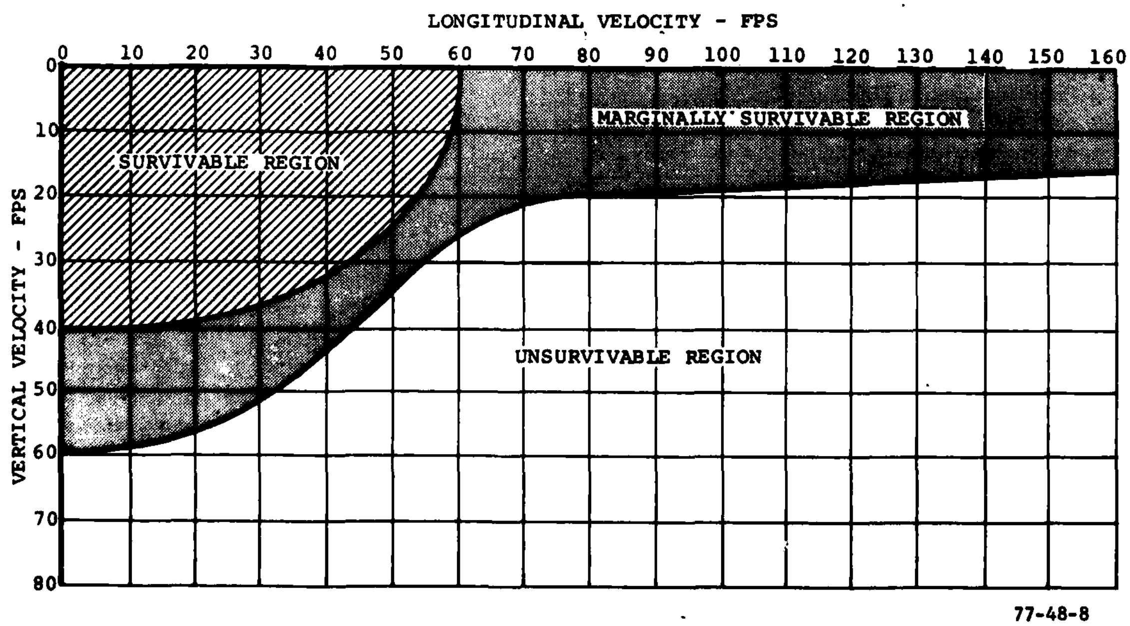

FIGURE 8. INITIAL IMPACT VELOCITIES (BASED ON ACCIDENT CASE HISTORIES OF MILITARY AND CIVILIAN AIRCRAFT)

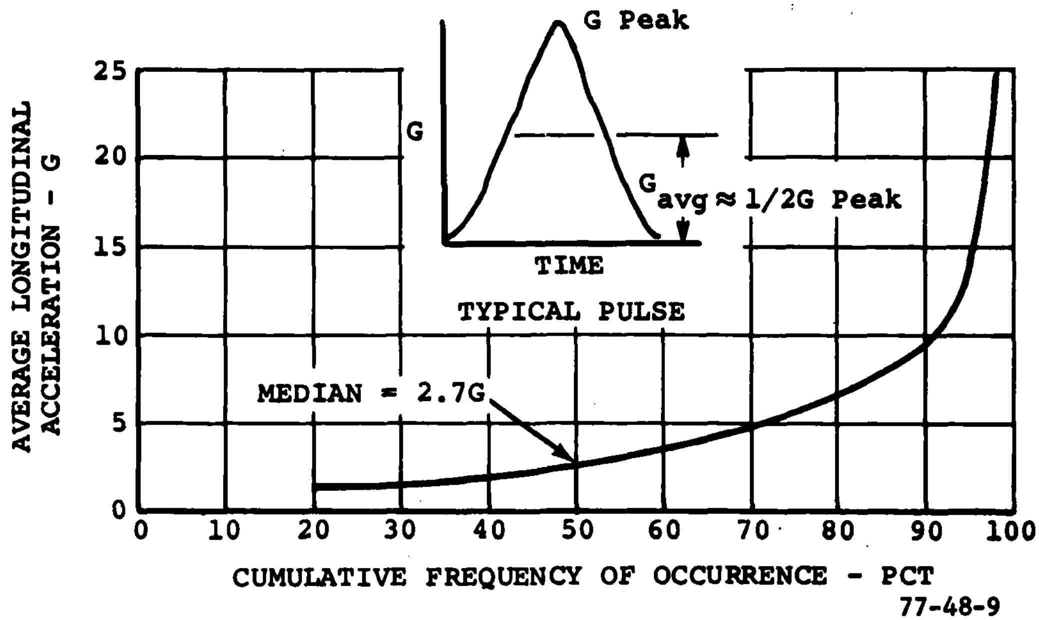

FIGURE 9. DISTRIBUTION OF AVERAGE LONGITUDINAL IMPACT ACCELERATIONS FOR ROTARY AND LIGHT FIXED-WING AIRCRAFT

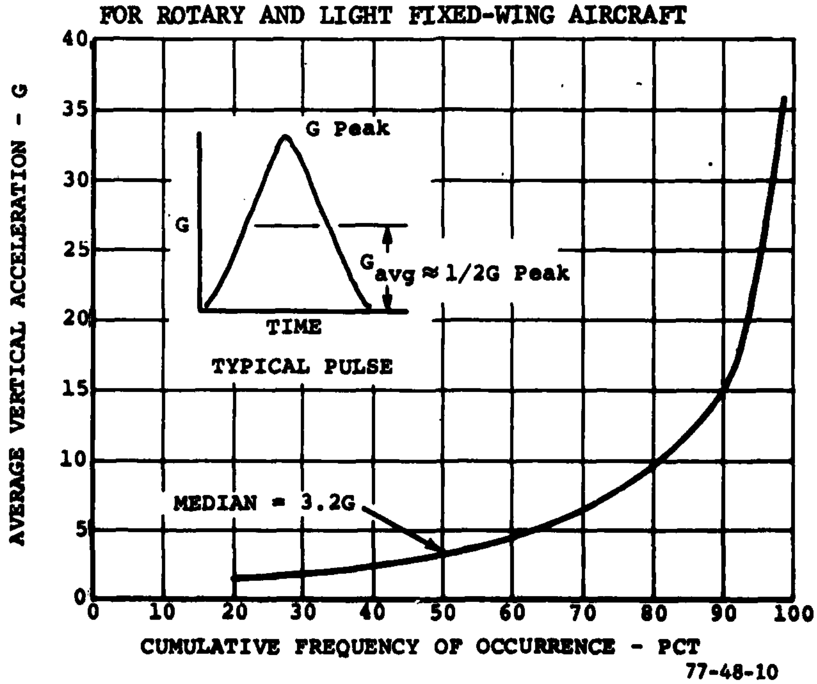

FIGURE 10. DISTRIBUTION OF AVERAGE VERTICAL IMPACT ACCELERATIONS FOR ROTARY AND LIGHT FIXED-WING AIRCRAFT

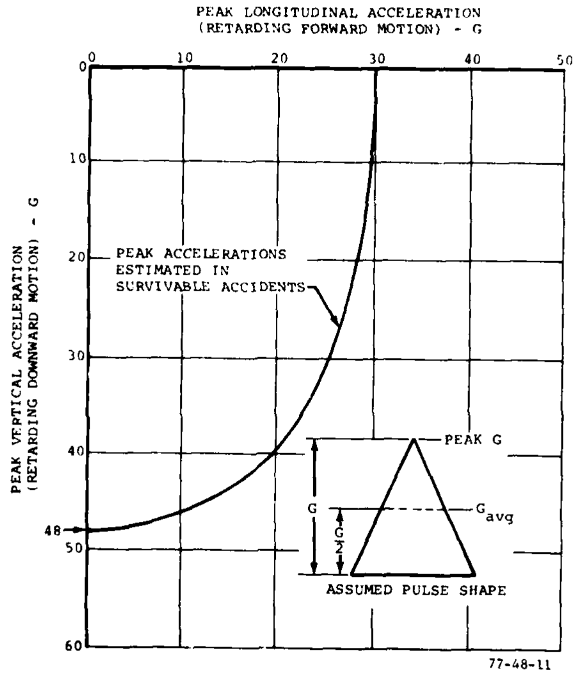

FIGURE 11. PEAK ACCELERATIONS ESTIMATED AT AIRCRAFT FLOOR LEVEL FOR THE 95TH PERCENTILE

FIGURE 12. NOSE GEAR TOWING ATTACHMENT

FIGURE 13. CRASH TEST SITE

FIGURE 14. AIRCRAFT IN POSITION FOR TEST

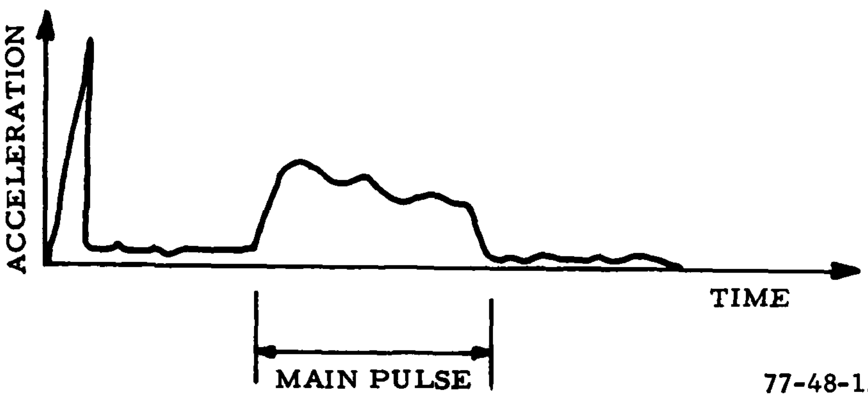

FIGURE 15. TYPICAL ACCELERATION PULSE

FIGURE 16. DAMAGE TO LEFT WING TWO-PLY FUEL TANK, TEST 1

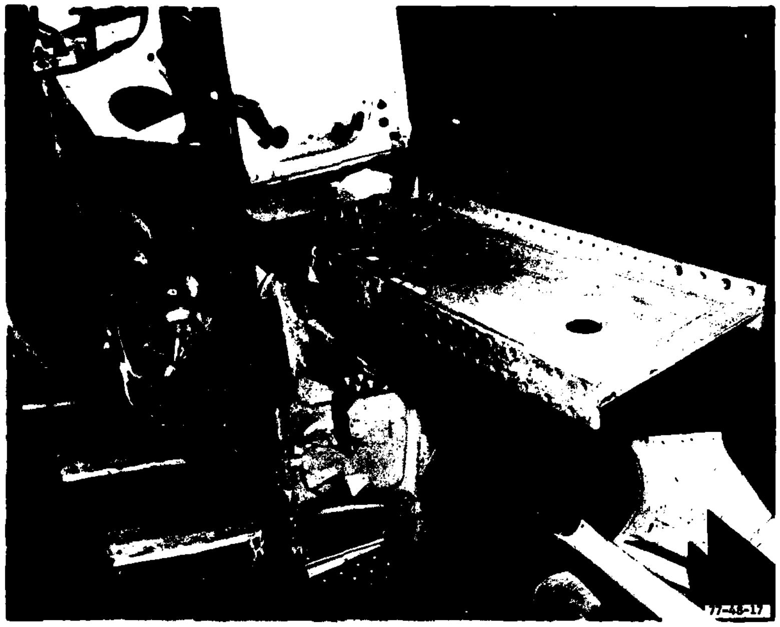

FIGURE 17. FAILURE OF MAIN SPAR, LEFT WING, TEST 1

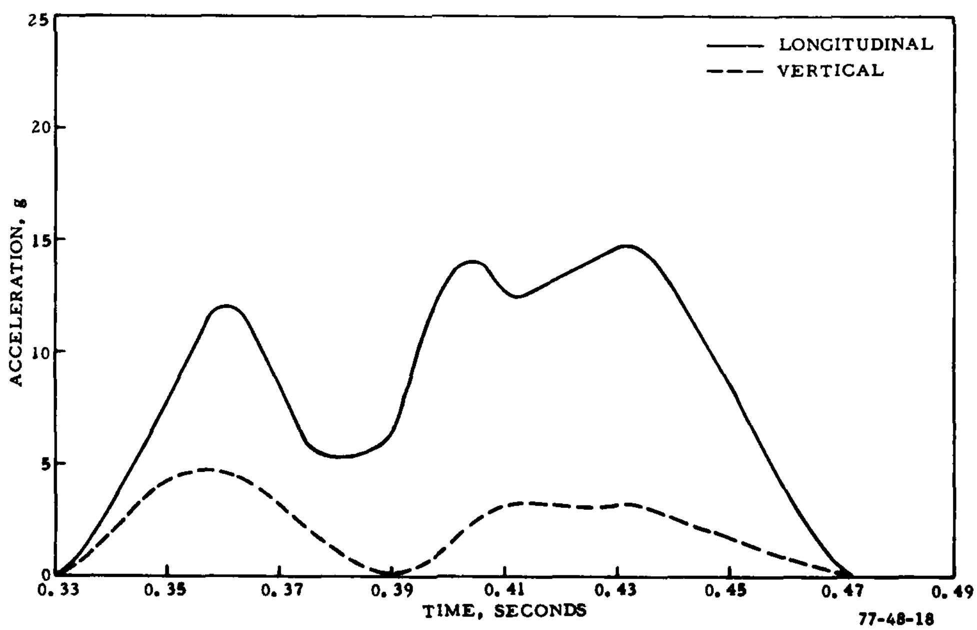

FIGURE 18. MAIN ACCELERATION PULSE, TEST 1

FIGURE 19. AIRCRAFT IMPACT, TEST 2, (NOTE WATER SPRAY FROM RIGHT WING)

FIGURE 20. DAMAGE TO RIGHT WING, ORIGINAL AIRCRAFT BLADDER CELL, TEST 2

FIGURE 21. DAMAGE TO RIGHT WING, ORIGINAL AIRCRAFT BLADDER CELL, TEST 2

FIGURE 22. DAMAGE TO LEFT WING, TWO-PLY FUEL TANK, TEST 2

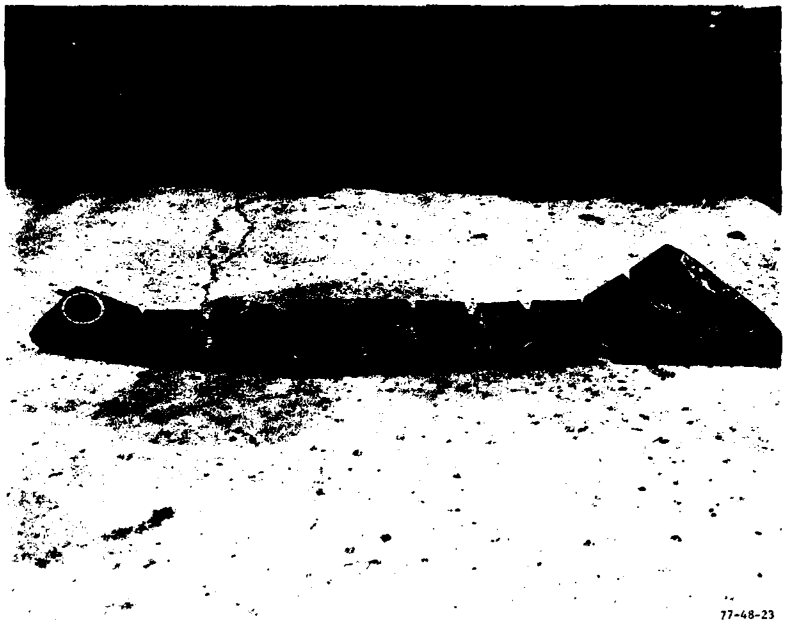

FIGURE 23. REGULAR (NON-CRASH-RESISTANT) BLADDER CELL AFTER IMPACT

FIGURE 24. DAMAGE TO REGULAR AIRCRAFT CELL DUE TO POLE IMPACE (INBOARD)

FIGURE 25. DAMAGE TO REGULAR AIRCRAFT CELL DUE TO POLE IMPACT (OUTBOARD)

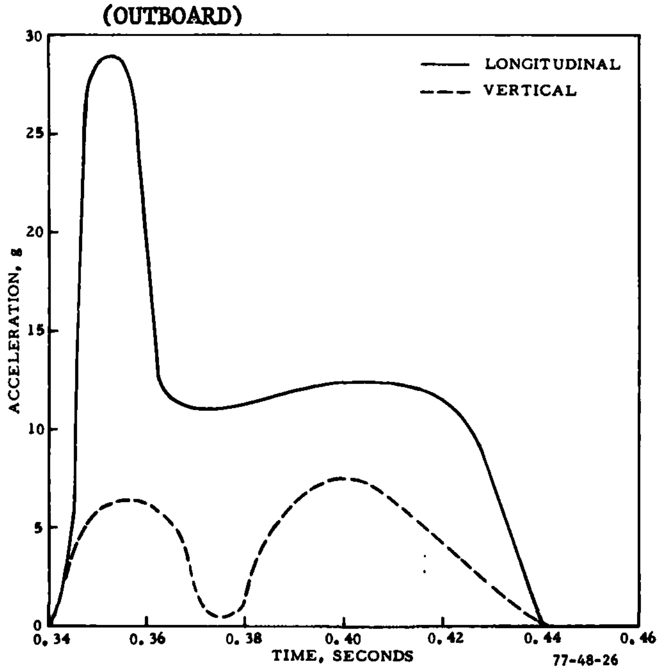

FIGURE 26. MAIN ACCELERATION PULSE, TEST 2

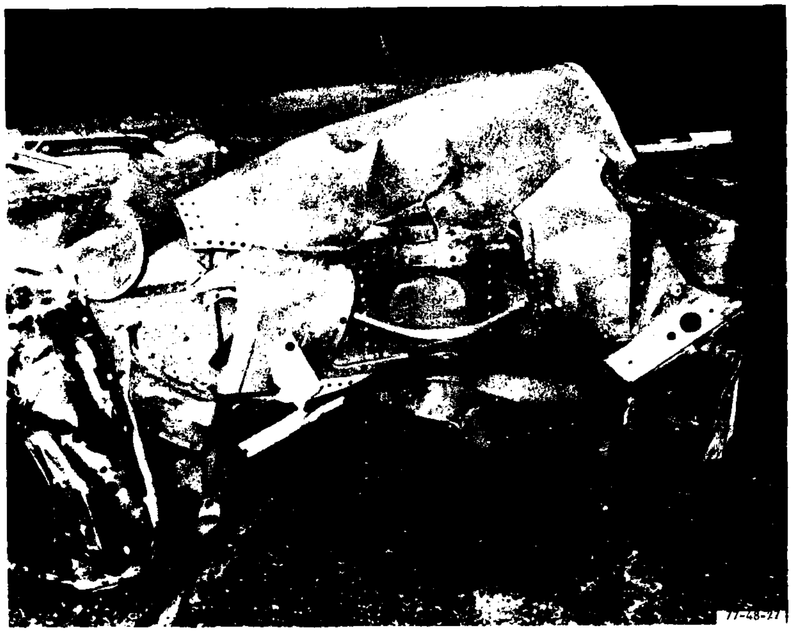

FIGURE 27. DAMAGE TO LEFT WING, TEST 3

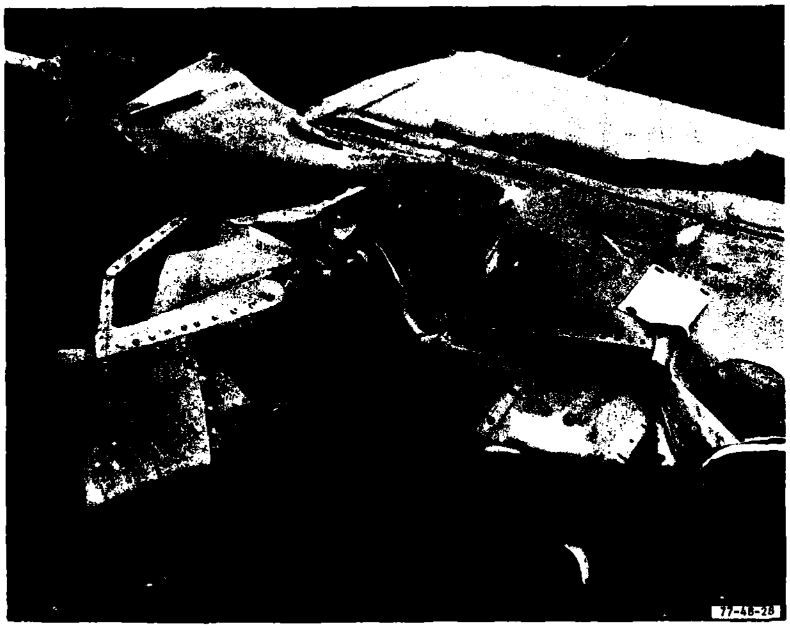

FIGURE 28. DAMAGE TO RIGHT WING, TEST 3

FIGURE 29. EFFECT OF ROCK IMPACT, TEST 3

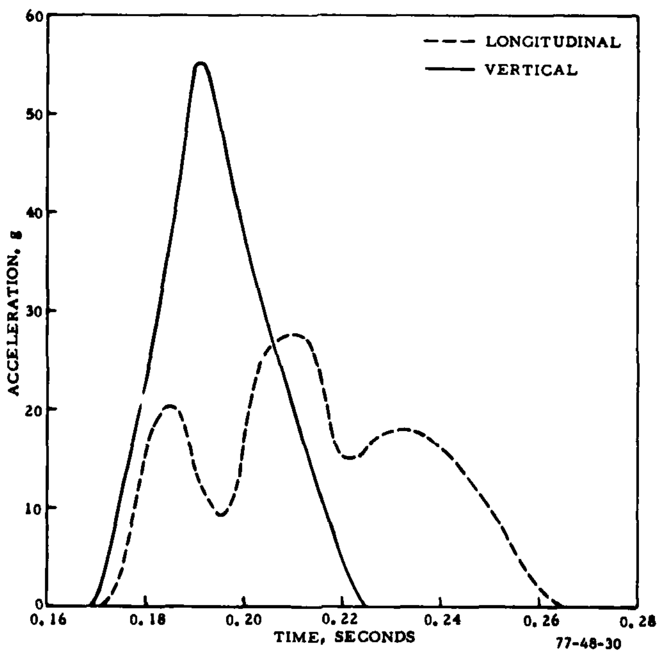

FIGURE 30. MAIN ACCELERATION PULSE, TEST 3

APPENDIX A

ORIGINAL CONTRACT SPECIFICATIONS

STATEMENT OF WORK

A. Introduction

Post-crash fire accidents continue to cause a significant number of fatalities in general aviation operation. The most promising method of controlling post-crash fires, thus reducing these fatalities in small aircraft, is fuel containment. Suitable fuel containment can be provided by using flexible bladder-type fuel cells which through special construction are resistant to bursting and tearing when subjected to impact forces associated with survivable-type accidents.

Special areas for consideration are:

1. Tank seam failure or tank rupture

2. Tank impact penetration

3. Fitting pullout

United States Army Aviation Materiel Laboratories programs have developed crashworthy fuel cell materials for helicopter applications and have produced prototype cells for one currently-manufactured small fixed-wing aircraft. These cells, while most effective, impose weight and cost penalties which could be reduced for civil applications.

The purpose of this effort is to fabricate and test relatively lightweight, low cost, crash resistant fuel cells which will prevent massive fuel spillage in small aircraft survivable accidents.

B. Detailed Requirements

The contractor shall provide the necessary qualified personnel, facilities, materials, equipment and services to perform and conduct the following in the fabrication, testing and installation of candidate crashworthy fuel cells for a typical general aviation aircraft.

1. Fabricate three crashworthy fuel cells for the Piper Navajo aircraft. These three cells (referred to herein as B.1 cells) are to conform in size and shape to the main left fuel cell, Piper Aircraft Corp., Part No. 40518-00. All three cells shall contain two plies of 12-ounce-weight nylon fuel cell fabric.

One of these three cells will be used for the crash impact test of MIL-T-27422B, Part 4.6.7.9. as modified in paragraph B4 below. These cells shall include the following arrangement of materials in the construction.

a) An innerliner coating plus barriers and cements

b) Twelve-ounce nylon fabric, applied at 45°

c) Twelve-ounce nylon fabric, applied straight

d) An outercoat of fuel cell material

2. Fabricate three crashworthy fuel cells for the Piper Navajo aircraft conforming in size and shape to the main right fuel cell, Piper Part No. 40518-01. All three cells (referred to herein as B.2 cells) shall contain three plies of 12-ounce-weight nylon fuel cell fabric. If the left fuel cell fails, when subjected to the crash impact test of Mil-T-27422B, Part 4.6.7.9, as modified in paragraph B.4 below, then one of these three cells will be used for the cited crash impact test. These cells shall include the following arrangement of materials in the construction.

a) An innerlayer coating plus barriers and cements

b) Twelve-ounce nylon fabric, applied at 45°

c) Twelve-ounce nylon fabric, applied straight

d) Twelve-ounce nylon fabric, applied at 45°

e) An outercoat of fuel cell material

3. All openings in the tanks shall incorporate fittings adaptable to the breakway valve or to the frangible tank port to wing surface structure, whichever is required. Valve fittings shall be sized to that breakaway tank to fuel line valve which is an off-the-shelf item and closest in size to the fuel lines used in the Piper Navajo system. Other port fittings shall conform to the sizes existing in the operational cells presently manufactured for the Piper Navajo aircraft. If required, additional openings shall be provided to facilitate installation of valves.

4. Four (4) samples each of the constructions of the two tanks, B.1 and B.2, shall be subjected to each of the five (5) composite construction tests of Part 4.6.5 of Military Specification MIL-T-27422B, and (1) each of tanks B.1 and B.2 shall be subjected to the crash impact test of MIL-T-27422B, Part 4.6.7.9, with the exception that the test tank shall be dropped from a height of 39 feet onto the forward or leading edge of the tank. If construction B.1 passes the 39-foot drop, construction B.2 need not be drop tested. All tests shall be conducted at Contractor's facilities.

5. All materials, including the fittings, will conform to the requirements of MIL-T-27422B.

6. All workmanship will be in conformance with the high quality requirements of MIL-T-27422B, and those of the aircraft industry.